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CHEMICAL REACTION AND RADIATION EFFECTS ON MHD FLOW OVER AN EXPONENTIALLY STRETCHING SHEET WITH VISCOUS DISSIPATION AND HEAT GENERATION

P. SRINIVASA SAI[1], K. RAMAKRISHNA[2], N. PUPPALA[3] & K. JAYARAMI REDDY[4]

[1]Department of Mathematics, SS and N College, Narasaraopet, Guntur, Andhra Pradesh, India

[2]Post Doc Research Fellow, Agricultural sciences, New Mexico State University, USA

[3]Associate Professor, New Mexico State University, Clovern, NM, USA

[4]Department of Mathematics, K. L. University, Guntur, Andhra Pradesh, India

ABSTRACT

The steady two-dimensional laminar stream of a gooey incompressible electrically directing liquid over an exponentially extending sheet in the presence of magnetic field with viscous dissipation, heat generation, chemical reaction and radiative heat flux is studied. By suitable similarity transformation, the overseeing limit layer comparisons are changed to normal differential mathematical statements and illuminated numerically by utilizing fourth request Runge-Kutta technique with shooting method. The impacts of different overseeing parameters on the speed, temperature, focus, skin-erosion coefficient, Nusselt number and Sherwood number are registered and examined in subtle element. Comparisons with previously published work are performed and are found to be in a good agreement.

KEYWORDS: Exponentially Stretching Sheet, MHD, Boundary Layer Flow, Radiation, Chemical Reaction Parameter, Dissipation, Heat Generation Parameter

INTRODUCTION

In the most recent couple of decades, liquid stream with warmth and mass exchange on a constantly extending sheet has pulled in extensive consideration due to its numerous applications in businesses, designing and assembling methods. Illustrations of these applications incorporate the glass-fiber creation, wire drawing, paper generation, plastic sheets, metal and polymer handling businesses, hot moving and constant throwing of metals and turning of filaments. The kinematics of extending and the synchronous warming or cooling amid such methods assume an imperative part on the structure and nature of the last item. Numerous scientists enlivened by Sakiadis [1, 2] who launched the limit layer conduct examined the extending stream issue in different viewpoints. Augmentation to that, a careful arrangement was given by Crane [3] for a limit layer stream brought on by extending surface.

Gupta [4], Carragher and Crane [5], Dutta et al. [6] mulled over the warmth move in the stream over an extending surface considering distinctive parts of the issue. Magyari and Keller [7] watched that the investigation of limit layers on an exponentially extending consistent surface with an exponential temperature circulation. Sanjayanand and Khan [8] studied the heat and mass transfer in a viscoelastic boundary layer flow over an exponentially stretching sheet. They found that the viscoelastic parameter enhances the thermal boundary layer thickness. The effect of viscous dissipation on the mixed convection heat transfer from an exponentially stretching surface was studied by Partha *et al.* [9]. They observed a

rapid growth in the non-dimensional skin friction coefficient with the mixed convection parameter.

The attributes coveted of the last item in an expulsion methodology rely on upon the rate of extending and cooling. Subsequently, it is critical to have a controlled cooling environment where the stream over the extending sheet can be directed by outside offices like an attractive field. An exponential variety of an attractive field is utilized, among different applications, to focus the diamagnetic weakness of plasma. Pavlov [10] considered the magnetohydrodynamic stream of an incompressible gooey liquid over a straightly extending surface. Sarpakaya [11] extended Pavlov's work to non-Newtonian liquids. Ensuing studies by Andersson [12], Lawrence and Rao [13], Abel et al.[14], Cortell [15] concerned the magnetohydrodynamic stream of viscoelastic fluids over an extending sheet.

The majority of the prior work dismissed radiation impacts. In the event that the polymer expulsion methodology is put in a thermally controlled environment, radiation could get to be vital. Numerous analysts have considered the impact of warm radiation on streams over extending sheets. The impact of warm radiation on the limit layer stream because of an exponentially extending sheet is examined by Sajid and Hayat [16]. Studies by Raptis [17], Raptis and Perdikis [18] address the impact of radiation in different circumstances. The impacts of radiation on hydromagnetic limit layer stream of a consistently extending surface have pulled in extensive consideration as of late because of its various applications in industry. Kameswaran et al.[19] watched that radiation impacts on MHD Newtonian fluid stream because of an exponential extending sheet. Seini and Makinde [20] mulled over impacts of radiation and substance response on MHD limit layer stream over exponential extending surface. Siddheshwar and Mahabaleswar [21] concentrated on the impacts of radiation and warmth source on MHD stream of a viscoelastic fluid and warmth exchange over an extending sheet. Bidin and Nazar [22] contemplated the impacts of numerical arrangement of the limit layer stream over an exponentially extending sheet with warm radiation. Elbashbeshy and Dimian [23] investigated limit layer stream in the vicinity of radiation impact and warmth exchange over the wedge with a gooey coefficient. Warm radiation consequences for hydro-attractive stream because of an exponentially extending sheet were mulled over by Reddy and Reddy [24]. Raptis et al. [25] examined the impact of warm radiation on the magnetohydrodynamic stream of a gooey liquid past semi-unbounded stationary plate and Hayat et al. [26] amplified the examination for the second grade liquid. Jat and Gopi Chand [27] found that the effects of dissipation and radiation on MHD flow and heat transfer over an exponentially stretching sheet. Radiation effects on MHD flow past an exponentially accelerated isothermal vertical plate with uniform mass diffusion in the presence of a heat source was studied by Reddy *et al.* [28]. They observed that the speed abatements with an increment in the attractive parameter because of a resistive drag power which has a tendency to oppose the liquid stream and along these lines decreases the speed. The limit layer thickness was additionally found to decline with an increment in the attractive parameter.

Notwithstanding an attractive field and warm radiation, one needs to consider the gooey dissemination impacts because of frictional warming between liquid layers. The impact of thick dissemination in characteristic convection techniques has been examined by Gebhart [29] and Gebhart and Mollendorf [30]. They watched that the impact of thick dissemination is dominating in overwhelming regular convection and blended convection forms. They additionally demonstrated the presence of a similitude answer for the outer stream over an endless vertical surface with an exponential variety of surface temperature.

The investigation of warmth era or assimilation in moving liquids is critical in issues managing compound responses and those concerned with separating liquids. Heat era impacts may adjust the temperature dissemination and this

thusly can influence the molecule testimony rate in atomic reactors, electronic chips and semi conductor wafers. Albeit definite displaying of inward warmth era or ingestion on is truly troublesome, some basic scientific models can be utilized to express its general conduct for most physical circumstances. Vajravelu and Hadjinicalaou [31] studied the heat transfer characteristics over a stretching surface with viscous dissipation in the presence of internal heat generation or absorption. Mohammed Ibrahim and Bhaskar Reddy [32] noticed that effects of radiation and mass transfer effects on MHD flow along a stretching surface in presence of viscous dissipation and heat generation. Pavithra and Gireesha [33] noticed that the effect of heat generation on dusty fluid flow over an exponentially stretching sheet with viscous dissipation. Mohammed Ibrahim [34] found that radiation effects on mass transfer flow passing through a highly porous medium in presence of heat generation and chemical reaction. Mohammed Ibrahim [35] investigated effects of chemical reaction and radiation on MHD free convection flow along a stretching surface in presence of dissipation and heat generation.

In the present article, we investigate the effects of various physical and fluid parameters such as the magnetic parameter, radiation parameter, viscous dissipation parameter, heat generation parameter and chemical reaction parameter on the flow, heat and mass transfer characteristics of an exponentially stretching sheet. The force, vitality and fixation mathematical statements are coupled and nonlinear. By utilizing suitable comparability variables, these comparisons are coupled and nonlinear. By utilizing suitable comparability variable, these comparisons are changed over into coupled customary differential mathematical statements and are illuminated numerically by utilizing shooting procedure with the forward request Range-Kutta strategy.

Formulation of the Problem

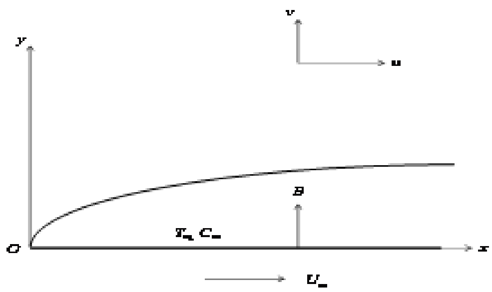

Figure 1: Schematics of the Problem

Consider an enduring two dimensional laminar stream of a thick incompressible electrically leading liquid over a continuous exponentially stretching surface. The *x* – axis is taken along the stretching surface in the direction of motion and *y*- axis is perpendicular to it. The sheet velocity is assumed to vary as an exponential function of the distance *x* from the slit. The temperature and concentration far away from the fluid are assumed to be T_∞ and C_∞ respectively as shown in Figure 1. The sheet-ambient temperature and concentration differences are also assumed to be exponential functions of the distance *x* from the slit. A variable magnetic field of strength *B(x)* is applied normally to the sheet. Under the usual boundary layer approximation, subject to radiation, viscous dissipation, heat generation and chemical reaction effects, the equations governing the momentum, heat and mass transports can be written as

Continuity equation

$$\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}=0 \tag{1}$$

Momentum equation

$$u\frac{\partial u}{\partial x}+v\frac{\partial v}{\partial y}=\nu\frac{\partial^2 u}{\partial y^2}-\frac{\sigma B_0^2}{\rho}u \tag{2}$$

Energy equation

$$u\frac{\partial T}{\partial x}+v\frac{\partial T}{\partial y}=\frac{k}{\rho c_p}\frac{\partial^2 T}{\partial y^2}-\frac{1}{\rho c_p}\frac{\partial q_r}{\partial y}+\frac{\nu}{c_p}\left(\frac{\partial u}{\partial y}\right)^2+\frac{\sigma B^2}{\rho c_p}u^2+\frac{Q_0}{\rho c_p}\left(T-T_\infty\right) \tag{3}$$

Species equation

$$u\frac{\partial C}{\partial x}+v\frac{\partial C}{\partial y}=D\frac{\partial^2 C}{\partial y^2}-Kr^*\left(C-C_\infty\right) \tag{4}$$

where *u* and *v* are the velocity components in the *x, y* directions respectively, ν is the kinematic viscosity, ρ is the density, σ is the electrical conductivity of the fluid, *T* is the temperature, *C* is the concentration, *k* is the thermal conductivity, c_p is the specific heat at constant pressure, q_r is the radiative heat flux, Q_0 is the heat generation coefficient, *D* is the species diffusivity, Kr^* is the reaction rate parameter.

The boundary conditions for the velocity, temperature and concentration fields are

$$u=U_w=U_0e^{\frac{x}{L}},\ v=0,\ T=T_w=T_\infty+T_0e^{\frac{2x}{L}},\ C=C_w=C_\infty+C_0e^{\frac{2x}{L}}\quad at\ y=0$$

$$u\to 0,\ T\to T_\infty,\ C\to C_\infty\ \ as\ \ y\to\infty \tag{5}$$

Here the subscripts w,∞ refer to the surface and ambient conditions respectively, T_0, C_0 are positive constants, U_0 is the characteristic velocity, *L* is the characteristic length and *Q* is the constant.

To facilitate a similarity solution, the magnetic field *B(x)* is assumed to be of the form

$$B(x)=B_0e^{\frac{x}{2L}} \tag{6}$$

where B_0 is a constant. It is also assumed that the fluid is weakly electrically conducting so that the induced magnetic field is negligible. Following Rosseland's approximation, the radiative heat flux q_r is modeled as

$$q_r=-\frac{4\sigma^*}{3k^*}\frac{\partial T^4}{\partial y} \tag{7}$$

where σ^* is the Stefan-Boltzman constant, k^* is the mean absorption coefficient.

This estimate is substantial at focuses optically a long way from the limit surface and it is useful for serious ingestion, which is for an optically thick limit layer. It is expected that the temperature contrast inside the stream such that the term T^4 may be communicated as a straight capacity of temperature. Subsequently, growing T^4 by Taylor series about T_∞ and disregarding higher-order terms

$$T^4 \equiv 4T_\infty^3 T - 3T_\infty^4$$

We have $$\frac{\partial q_r}{\partial y} = -\frac{16\sigma^* T_\infty^3}{3k^*}\frac{\partial^2 T}{\partial y^2} \tag{8}$$

Continuity equation (1) is satisfied by introducing a stream function ψ such that

$$u = \frac{\partial \psi}{\partial y}, \quad v = -\frac{\partial \psi}{\partial x} \tag{9}$$

The following similarity variables are used:

$$u = U_0 e^{\frac{x}{L}} f'(\eta), \quad v = -\sqrt{\frac{\nu U_0}{2L}}\, e^{\frac{x}{2L}} \left(f(\eta) + \eta f'(\eta) \right)$$

$$T = T_\infty + T_0 e^{\frac{2x}{L}} \theta(\eta), \quad C = C_\infty + C_0 e^{\frac{2x}{L}} \phi(\eta), \quad \eta = \sqrt{\frac{U_0}{2\nu L}}\, y e^{\frac{x}{2L}} \tag{10}$$

Where η is the similarity variable, $f(\eta)$ is the dimensionless stream function, $\theta(\eta)$ is the dimensionless temperature, and $\phi(\eta)$ is the dimensionless concentration.

On using equations (6), (8) and (10), equations (2) – (5) are transformed to:

$$f''' - 2f'^2 + ff'' - Mf' = 0 \tag{11}$$

$$\left(1 + \frac{4}{3}R\right)\theta'' + \Pr\left[f\theta' - f'\theta + Ec(f'')^2 + MEc(f')^2 + Q\theta \right] = 0 \tag{12}$$

$$\phi'' + Scf\phi' - Scf'\phi - ScKr\phi = 0 \tag{13}$$

$$f(0) = 0, \quad f'(0) = 1, \quad f'(\infty) \to 0, \tag{14}$$

$$\theta(0) = 1, \quad \theta(\infty) \to 0, \tag{15}$$

$$\phi(0) = 1, \quad \phi(\infty) \to 0. \tag{16}$$

The non-dimensional constants showing up in mathematical statements (11) – (13) are the magnetic parameter M,

the radiation parameter R, the Prandtl number Pr, the Eckert number Ec, Q is the heat generation parameter, Sc is the Schmidth number and Kr is the chemical reaction parameter individually characterized

$$M = \frac{2\sigma B_0^2 L}{\rho U_0} \quad R = \frac{4\sigma^* T_\infty^3}{k^* k}, \quad \Pr = \frac{\rho \nu c_p}{k} \quad Ec = \frac{U_0^2}{c_p T_0}$$

$$Q = \frac{2Q_0 L}{U_0 e^{\frac{x}{L}}}, \quad Sc = \frac{\nu}{D}, \quad Kr = \frac{2LKr^*}{U_0}$$

Skin Friction, Heat and Mass Transfer Coefficients

The parameters of designing enthusiasm for warmth and mass transport issues are the skin erosion coefficient, the neighborhood Nusselt number Nu, and the nearby Sherwood number Sh. These parameters separately describe the surface drag, divider warmth and mass exchange rates.

The shearing stress at the surface of the wall τ_w is given by

$$\tau_w = -\mu \left(\frac{\partial u}{\partial y} \right)_{y=0} = -\frac{\mu U_0}{L} \sqrt{\frac{\mathrm{Re}}{2}} \; e^{\frac{3x}{2L}} f''(0), \tag{17}$$

where μ is the coefficient of viscosity and $\mathrm{Re} = \frac{U_0 L}{\nu}$ is the Reynolds number. The skin friction coefficient is defined as

$$C_f = \frac{2\tau_w}{\rho U_w^2} \tag{18}$$

and using equation (17) in equation (18), we obtain

$$\frac{C_f \sqrt{\mathrm{Re}/2}}{\sqrt{x/L}} = -f''(0). \tag{19}$$

The heat transfer rate at the surface flux at the wall is given by

$$q_w = -k \left(\frac{\partial T}{\partial y} \right)_{y=0} = \frac{-k(T_w - T_\infty)}{L} \sqrt{\frac{\mathrm{Re}}{2}} \; e^{\frac{x}{2L}} \theta'(0), \tag{20}$$

where *k* is the thermal conductivity of the fluid. The Nusselt number is defined as

$$Nu = \frac{x}{k} \frac{q_w}{T_w - T_\infty}. \tag{21}$$

Using Equation (20) in Equation (21), the dimensionless wall heat transfer rate is obtained as follows:

$$\frac{Nu}{\sqrt{x/L}\sqrt{\mathrm{Re}/2}} = -\theta'(0) \quad . \tag{22}$$

The mass flux at the surface of the wall is given by

$$J_w = -D\left(\frac{\partial C}{\partial y}\right)_{y=0} = \frac{-D(C_w - C_\infty)}{L}\sqrt{\frac{\mathrm{Re}}{2}} \quad e^{\frac{x}{2L}}\phi'(0) \tag{23}$$

The Sherwood number is defined as

$$Sh = \frac{x}{D}\frac{J_w}{C_w - C_\infty}. \tag{24}$$

Using (23) in (24), the dimensionless wall mass transfer rate is obtained as

$$\frac{Sh}{\sqrt{x/L}\sqrt{\mathrm{Re}/2}} = -\phi'(0) \tag{25}$$

In Equations (19), (22) and (25), *Re* represents the local Reynolds number and it is defined as

$$\mathrm{Re} = \frac{xU_w}{\nu}.$$

Numerical Procedure

The set of nonlinear ordinary differential equations (11), (12), and (13) with boundary conditions (14) - (16) were solved numerically using Runge – Kutta fourth order algorithm with a systematic guessing of $f''(0)$, $\theta'(0)$ and $\phi'(0)$ by the shooting technique until the boundary conditions at infinity are satisfied. The step size $\Delta\eta$ = 0.001 is used while obtaining the numerical solution and accuracy up to the fifth decimal place i.e. 1×10^{-5}, which is very sufficient for convergence. In this method, we choose suitable finite values of $\eta \to \infty$, say η_∞, which depend on the values of the parameter used. The computations were done by a program which uses a symbolic and computational computer language in Mathematica.

RESULTS AND DISCUSSIONS

To dissect the outcomes, numerical calculation has been done utilizing the system depicted as a part of the past passage for different in representing parameters, in particular, magnetic field parameter M, Prandlt number Pr, radiation parameter R, heat generation parameter Q, Eckert number Ec, Schmidt number Sc, chemical reaction parameter Kr. In the present study taking after default parameter qualities are received for processings:*M = 1.0, Pr = 0.71, R = 0.5, Q = 0.1, Ec = 0.1, Sc = 0.6, Kr = 0.5.* All graphs therefore correspond to these values unless specifically indicated on the appropriate graph.

Figure 2 shows the variation of the velocity profile against the magnetic parameter. We notice that the effect of the magnetic parameter is to reduce the velocity of the fluid in the boundary layer region. This is due to an increase in the

Lorentz force, similar to Darcy's drag observed in the case of flow through a porous medium. This adverse force is responsible for slowing down the motion of the fluid in the boundary layer region.

The variation of the temperature distribution with the magnetic parameter is shown in Figure 3. The thermal boundary layer thickness increases with increasing values of the magnetic parameter. The opposing force introduced in the form of the Lorentz drag contributes in increasing the frictional heating between the fluid layers, and hence energy is released in the form of heat. This results in thickening of the thermal boundary layer.

The effect of the magnetic parameter on the concentration profile is shown in Figure 4. It is observed that increases in the values in *M* result in thickening of the species boundary layer.

Figure 5 illustrates the temperature profile for different values of the Prandtl number *Pr*. The Prandtl number defines the ratio of momentum diffusivity to thermal diffusivity. The numerical results show the effect of increasing values of Prandtl number results in decreasing temperature. The reason is that smaller values of Prandtl number *Pr* are equivalent to increasing the thermal conductivities, and therefore heat is able to diffuse away from the heated plate more rapidly than for higher values of Prandtl number *Pr*. Hence in the case of smaller Prandtl number *Pr* as the boundary layer is thicker and the rate of heat transfer is reduced.

The influence of the thermal radiation parameter *R* on temperature is shown in Figure 6. It is clear that thermal radiation enhances the temperature in the boundary layer region. Thus radiation should be kept at its minimum in order to facilitate better cooling environment. The radiation parameter *R* defines the relative contribution of conduction heat transfer to thermal radiation transfer.

The effect of the Eckert number *Ec* on heat transfer is shown in Figure 7. It is clear that the temperature in the boundary layer region increases with an increase in the viscous dissipation parameter.

Figure 8 shows the influence of the heat generation parameter *Q* on the temperature profile within the thermal boundary layer. From the Figure 8 it is observed that the temperature increases with an increase in the heat generation parameter.

Figures 9-10 depict chemical species concentration profiles against co-ordinate η for varying values physical parameters in the boundary layer. The species concentration is highest at the plate surface and decreases to zero far away from the plate satisfying the boundary condition. From these figures, it is noteworthy that the concentration boundary layer thickness decreases with an increase in Schmidt number and chemical reaction parameter.

We likewise take note of that since the vitality mathematical statement is incompletely decoupled from the force and species preservation comparisons, the parameters influencing the vitality comparison, specifically, the Prandtl number, the thermal radiation parameter, heat generation parameter and the Eckert number, don't change velocity and concentration profiles. Table 1 shows the comparison of Kameswaran *et al.* [19] work with the present work for $Pr = R = Ec = Q = Sc = Kr = 0$ and it note worthy that there is a good agreement.

Table 2 indicates the values of skin-friction coefficient, the wall temperature gradient and the wall concentration gradient in terms of $-f''(0), -\theta'(0)$ and $-\phi'(0)$ respectively for various values embedded flow parameter. From Table 2, it is understood that, as increasing values of magnetic field parameter *(M)* results in considerable opposition to the flow in the form of a Lorenz drag which enhances the values of skin-friction coefficient, but there is a decrease in the wall

temperature gradient and the wall concentration gradient. The wall temperature gradient reduces as increase the values of radiation parameter *R* or dissipation *Ec* or heat generation parameter *Q*, while it is increases for increasing value of Prandtl number *Pr*. It is also observed that the increase in Schmidt number *Sc* or chemical reaction parameter *Kr* parameter lead to the increase in the dimensionless wall concentration gradient.

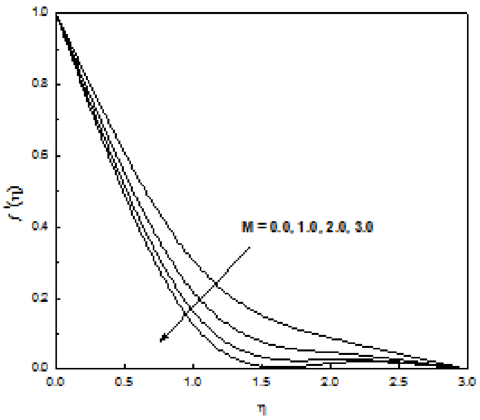

Figure 2: Velocity Profiles for Varying Values of Magnetic Parameter *(M)*

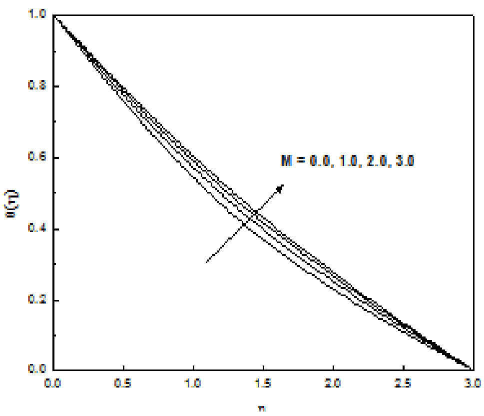

Figure 3: Temperature Profiles for Varying Values of Magnetic Parameter *(M)*

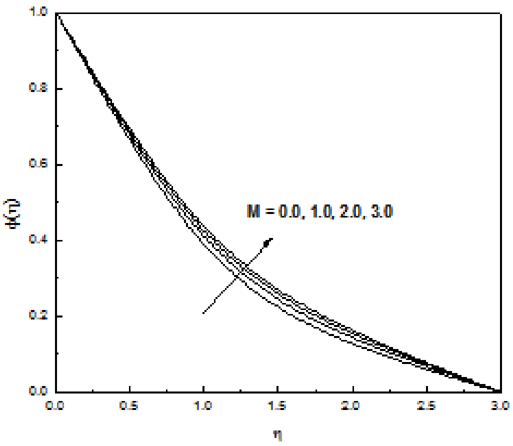

Figure 4: Concentration Profiles for Varying Values of Magnetic Parameter *(M)*

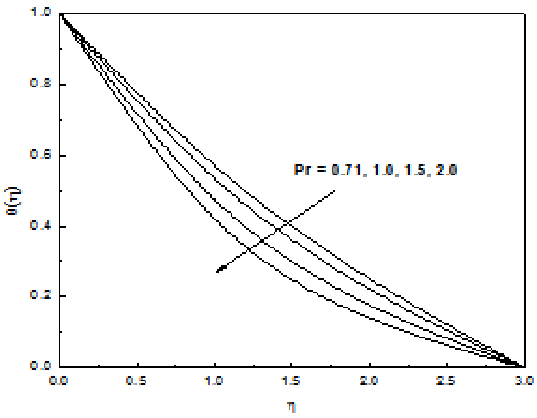

Figure 5: Temperature Profiles for Varying Values of Prandtl Parameter *(Pr)*

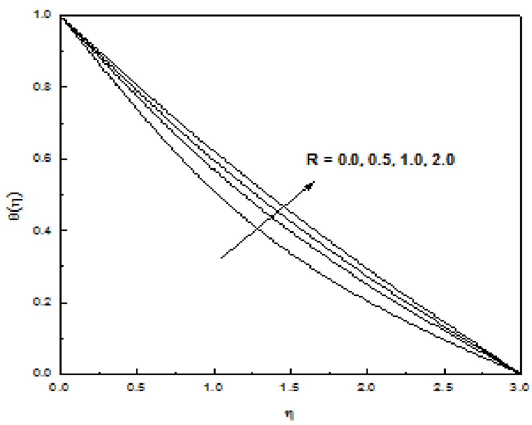

Figure 6: Temperature Profiles for Varying Values of Radiation Parameter *(R)*

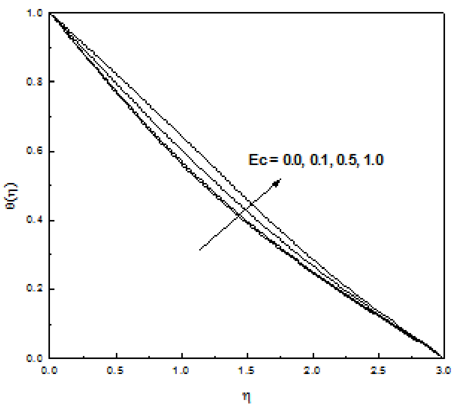

Figure 7: Temperature Profiles for Varying Values of Viscous Dissipation Parameter *(Ec)*

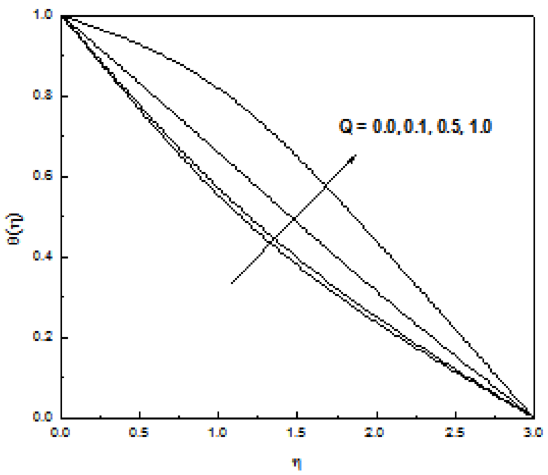

Figure 8: Temperature Profiles for Varying Values of Heat Generation Parameter *(Q)*

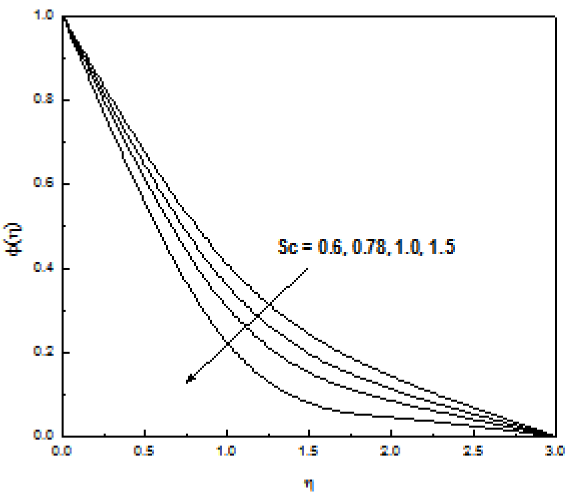

Figure 9: Concentration Profiles for Varying) Values of Schmidt Parameter *(Sc)*

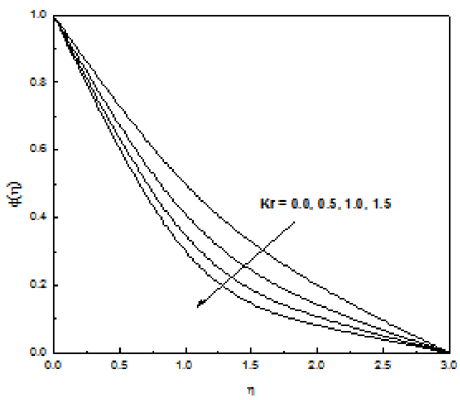

Figure 10: Concentration Profiles for Varying Reaction Rate Parameter *(Kr)*

Table 1: A Comparison of Skin-Friction Coefficient $-f''(0)$ for Different Values of *M* for Fixed Values of *Pr = R = Q = Ec = Sc = Kr = 0*

	$-f''(0)$	
M	**Kameswaran *et al.* [19]**	**Present**
0.0	1.28181	1.29038
1.0	1.62918	1.63038
2.0	1.91262	1.91285
3.0	2.15874	2.15879
4.0	2.37937	2.37938

Table 2: Computation Showing $-f''(0)$, $-\theta'(0)$ and $-\phi'(0)$ for Different Embedded Flow Parameter Values

M	*Pr*	*R*	*Ec*	*Q*	*Sc*	*Kr*	$-f''(0)$	$-\theta'(0)$	$-\phi'(0)$
1.0	0.71	0.5	0.1	0.1	0.6	0.5	1.63038	0.518152	0.898172
2.0	0.71	0.5	0.1	0.1	0.6	0.5	1.91285	0.47744	0.873141
3.0	0.71	0.5	0.1	0.1	0.6	0.5	2.15879	0.445763	0.854063
1.0	1.0	0.5	0.1	0.1	0.6	0.5	1.63038	0.591577	0.898172
1.0	2.0	0.5	0.1	0.1	0.6	0.5	1.63038	0.832569	0.898172
1.0	0.71	1.0	0.1	0.1	0.6	0.5	1.63038	0.465892	0.898172

Table 2: Contd.,

1.0	0.71	2.0	0.1	0.1	0.6	0.5	1.63038	0.417967	0.898172
1.0	0.71	0.5	0.5	0.1	0.6	0.5	1.63038	0.355639	0.898172
1.0	0.71	0.5	1.0	0.1	0.6	0.5	1.63038	0.152498	0.898172
1.0	0.71	0.5	0.1	0.5	0.6	0.5	1.63038	0.354218	0.898172
1.0	0.71	0.5	0.1	1.0	0.6	0.5	1.63038	0.0846552	0.898172
1.0	0.71	0.5	0.1	0.1	0.78	0.5	1.63038	0.518152	1.03456
1.0	0.71	0.5	0.1	0.1	1.0	0.5	1.63038	0.518152	1.18749
1.0	0.71	0.5	0.1	0.1	0.6	1.0	1.63038	0.518152	1.06315
1.0	0.71	0.5	0.1	0.1	0.6	2.0	1.63038	0.518152	1.33022

CONCLUSIONS

In this article we have studied the effects of radiation and viscous dissipation on heat and mass transfer from an exponentially stretching surface in the presence of heat generation and chemical reaction. The governing equations were solved numerically using the Runge-Kutta fourth order along shooting method. This has been shown to give accurate results. The effects of various physical parameters on the fluid properties, the skin-friction coefficient and the heat and mass transfer rates have been determined. We found that the effect of the magnetic parameter is to reduce the velocity of the fluid in the boundary layer region. It was also observed that the increase in values of *M* results in thickening of the species boundary layer. The chemical concentration boundary layer was found to decrease near the boundary with increasing reaction rate parameter and the Schmidt parameters. The heat transfer rates increases with an increasing of individual effects of the magnetic parameter *M*, the radiation parameter *R*, heat generation parameter *Q* and Eckert number *Ec*. The mass transfer rate increases with an increasing of Schmidt parameter *Sc* or the rate reaction parameter *Kr.* Also the numerical results obtained are agrees with previously reported case available in the literature Kameswaran *et al.* [27].

REFERENCES

1. Sakiadis BC (1961), Boundary layer behavior on continuous solid surface I: Boundary-layer equations for two dimensional and axisymmetric flow, *AIChE Journal*, vol. 7, no. 1, pp. 26–28.
2. Sakiadis BC (1961), Boundary layer behaviour on continuous solid surface II: Boundary layer behavior on continuous flat surface, *AIChE Journal*, vol. 7, no. 2, pp. 221–235.
3. Crane LJ (1970), Flow past a stretching plate, *Zeitschrift F¨ur AngewandteMathematik und Physik ZAMP*, vol. 21, no. 4, pp. 645–647.
4. Gupta PS and Gupta AS (1977), Heat and mass transfer on stretching sheet with suction or blowing, *Can. J. Chem. Eng*., Vol. 55, pp. 744-746.
5. Carragher P and Crane LJ (1982), Heat transfer on a continuous stretching sheet, *Z. Angew. Math. Mech.*, Vol. 62, pp. 564-573.
6. Dutta BK., Roy P and Gupta A. S (1985), Temperature field in flow over a stretching surface with uniform heat flux, *Int. Comm. Heat Mass Transfer.* Vol. 12, pp. 89-94.
7. Magyari E and Keller B (1999), Heat and transfer in the boundary layers on an exponentially stretching continuous surface, *J. Phys. D: Appl.Phys.*, Vol. 32, pp. 577-585.
8. Sanjayanand E, Khan SK (2006), On heat and mass transfer in a viscoelastic boundary layer flow over an

exponentially stretching sheet. *Int. J. Therm. Sci.*, Vol. 45, pp.819-828.

9. Partha MK, Murthy PVSN, Rajasekhar GP (2005), Effect of viscous dissipation on the mixed convection heat transfer from an exponentially stretching surface. *Heat Mass Transfer.* Vol. 41, pp. 360-366.
10. Pavlov KB (1974), Magnetohydromagnetic flow of an incompressible viscous fluid caused by deformation of a surface. *Magn. Gidrodin*. Vol. 4, pp. 146-147.
11. Sarpakaya T (1961), Flow of non-Newtonian fluids in a magnetic field. *AIChE J.* Vol. 7, pp. 324-328.
12. Andersson HI (1992), MHD flow of a viscoelastic fluid past a stretching surface. *Acta Mech.* Vol. 95, pp. 227-230.
13. Lawrence PS and Rao BN (1995), The non-uniqueness of the MHD flow of a viscoelastic fluid past a stretching sheet. *Acta Mech.* Vol. 112, pp. 223-228.
14. Abel MS., Joshi A, and Sonth RM (2001), Heat transfer in MHD viscoelastic fluid flow over a stretching surface. *Z. Angew. Math. Mech*. Vol. 81, pp. 691-698.
15. Cortell R (2006), Flow and heat transfer of an electrically conducing fluid of second grade over a stretching sheet subject to suction and to a transverse magnetic field. *Int. J. Heat Mass Transfer*, Vol. 49, pp. 1851-1856.
16. Sajid M and Hayat T (2008), Influence of thermal radiation on the boundary layer flow due to an exponentially stretching sheet. *Int. Commun. Heat Mass Transfer.* Vol. 35, pp. 347-356.
17. Raptis A (1999), Radiation and viscoelastic flow. *Int. Commun. Heat Mass Transfer*, Vol. 26, No. 6, 889-895.
18. Raptis A and Perdikis C (1998), Viscoelastic flow by the presence of radiation. *Z. Angew. Math. Mech*, Vol. 78, pp. 277-279.
19. Kameswaran PK., Narayana M., Sibanda P, and Makanda G (2012), On radiation effects on hydromagnetic Newtonian liquid flow due to an exponential stretching sheet, *Boundary Value Problems*, Vol. 105, pp. 1-16.
20. Seini YI and Makinde OD (2013) MHD boundary layer flow due to exponential stretching surface with radiation and chemical reaction, *Mathematical Problems in Engineering*, Vol. 2013, Article ID 163614, Pages 7.
21. Siddheshwar PG and Mahabaleswar US (2005), Effects of radiation and heat source on MHD flow of a viscoelastic liquid and heat transfer over a stretching sheet. *Int. J. Non-Linear Mech*, Vol. 40, pp. 807-820.
22. Bidin B and Nazar R (2009), Numerical solution of the boundary layer flow over an exponentially stretching sheet with thermal radiation. *Eurp. J. Sci. Res*, Vol. 33, No. 4, pp. 710-717.
23. Elbashbeshy EMA and Dimian MF (2002), Effect of radiation on the flow and heat transfer over a wedge with variable viscosity. *Appl. Math. Comput*, Vol. 132, pp. 445-454.
24. Reddy PBA and Reddy NB (2011), Thermal radiation effects on hydromagnetic flow due to an exponentially stretching sheet, *Int. J. Appl. Math. Comput*, Vol. 3, Vol. 4, pp. 300-306.
25. Raptis A., Perdikis C and Takhar HS (2004), Effect of thermal radiation on MHD flow. *Int. J. Heat Mass Transfer*, Vol. 153, pp. 645-649.

26. Hayat T., Abbas Z, Sajid M and Asghar S (2007), The influence of thermal radiation on MHD flow of a second grade fluid. *Int. J. Heat Mass Transfer*, Vol. 50, pp. 931-941.

27. Jat RN and Gopi Chand (2013), MHD flow and heat transfer over an exponentially stretching sheet with viscous dissipation and radiation effects, *Applied Mathematical Sciences*, Vol.7, No.4, pp. 167-180.

28. Reddy PBA., Reddy NB, and Suneetha S (2012), Radiation effects on MHD flow past an exponentially accelerated isothermal vertical plate with uniform mass diffusion in the presence of heat source. *J. Appl. Fluid Mech*, Vol. 5, No.3, pp. 119-126.

29. Gebhart B (1962), Effect of viscous dissipation in natural convection. *J. Fluid Mech*, Vol. 14, pp. 225-232.

30. Gebhart B and Mollendorf J (1969), Viscous dissipation in external natural convection flows. *J. Fluid Mech*, Vol. 38, pp. 97-107.

31. Vajravelu K and Hadjinicolaou A (1993), Heat transfer in a viscous fluid over a stretching sheet with viscous dissipation and internal heat generation. *Int. Commun. Heat Mass Transfer*, Vol. 20, pp. 417-430.

32. Mohammed Ibrahim S and Bhaskar Reddy N (2012), Radiation and Mass transfer effects on MHD free convection flow along a stretching surface with viscous dissipation and heat generation, *Int. J. of Appl. Math and Mech*. Vol. 8, No. 8, pp. 1-21.

33. Pavithra GM and Gireesha BJ (2013) Effect of internal heat generation/absorption on dusty fluid flow over an exponentially stretching sheet with viscous dissipation, *Journal of Mathematics*, Vol.2013, Article ID 583615, Pages 10.

34. Mohammed Ibrahim S (2013) Radiation effects on mass transfer flow through a highly porous medium with heat generation and chemical reaction, *ISRN Computational Mathematics*, Vol. 2013, Article ID 765408, pages 9.

35. Mohammed Ibrahim S (2013) Chemical reaction and radiation effects on MHD free convection flow along a stretching surface with viscous dissipation and heat generation, *Advances in Applied Science Research*, Vol. 4, No. 1, pp. 371-382.